MULTIMEDIA UNIVERSITY

STUDENT ID NO

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# MULTIMEDIA UNIVERSITY

# FINAL EXAMINATION

**TRIMESTER 2, 2017/2018**

## EEE2146 – MICROELECTRONIC CIRCUIT ANALYSIS AND DESIGN

( All sections / Groups )

12 MARCH 2018

9:00 AM to 11:00 AM

( 2 Hours )

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**INSTRUCTIONS TO STUDENTS**

1. This examination paper consists of 6 pages with 4 questions only.
2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

## Question 1

(a) Compute the transistor collector current, Ic, emitter current, $I_E$, emitter voltage, $V_E$ and base voltage, $V_B$ (with respect to ground) of the circuit shown in Figure Q1. Note that, the Thevenin's theorem should be used. Given that $V_{CC}$ = 10 V, the transistor $V_{BE(active)}$ = 0.7 V and current gain $\beta$ = 100.

[7 marks]

(b) Draw the small-signal equivalent circuit of the amplifier circuit in Figure Q1 using the simplified hybrid-$\pi$ model. Note that, the Early voltage $V_A = \infty$.

[5 marks]

(c) From the small-signal equivalent circuit, determine the small signal input resistance, $R_{IN}$ and the overall voltage gain. $G_v = \frac{V_O}{V_{Sig}}$. Given that voltage equivalence of temperature $V_T$ = 26 mV.

[13 marks]

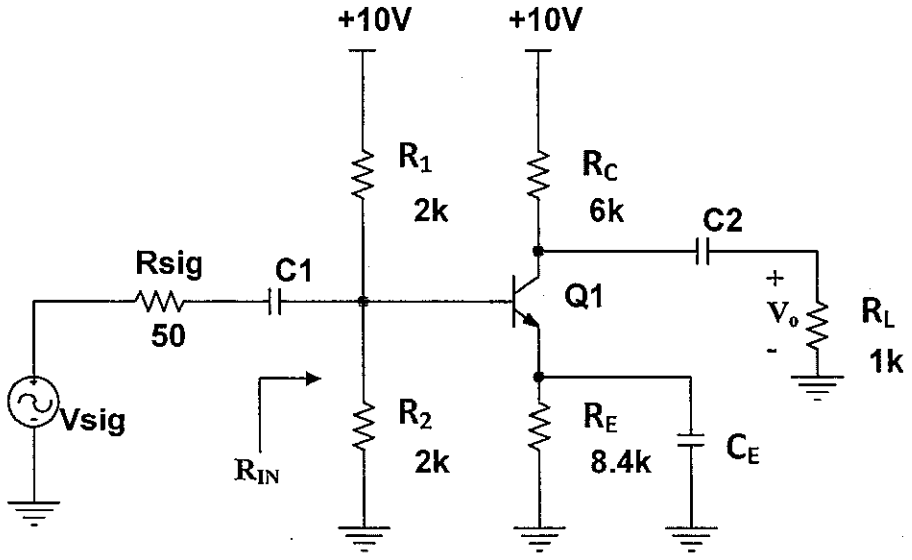


**Figure Q1**

**Continued...**

**Question 2**

The circuit shown in Figure Q2 is a common-gate amplifier. The NMOS transistor has $V_t = 1.5V$, $k'_n(W/L) = 1\ mA/V^2$ and $V_A = \infty$.

(a) From the DC analysis, by assuming the transistor is operating in saturation region, determine the overdrive voltage $V_{OV}$, the DC gate-source voltage $V_{GS}$, the DC gate voltage $V_G$, the DC source voltage $V_S$ and the DC drain voltage $V_D$. Assume the DC gate current, $I_G = 0$.

[7 marks]

(b) Draw a small-signal equivalent circuit for the circuit shown in Figure Q2 using the simplified T-model.

[5 marks]

(c) Refer to the small-signal equivalent circuit in part (b), derive and compute the small-signal input resistance, $R_{IN}$ and overall small-signal voltage gain, $G_v = \frac{v_O}{v_{isig}}$.

[13 marks]

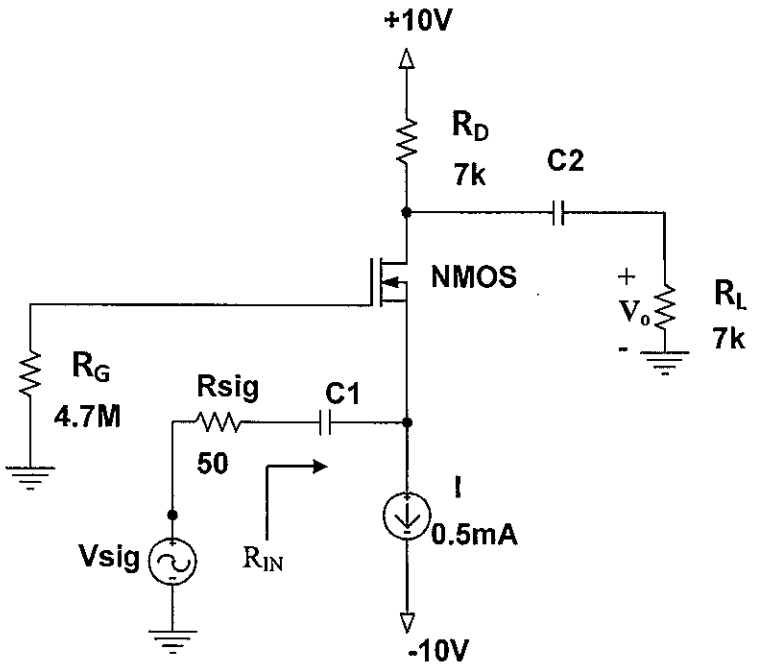


**Figure Q2**

**Continued...**

## Question 3

(a) Design the current mirror and differential amplifier as shown in Figure Q3 by finding the values of $R_1$, $R_{C1}$ and $R_{C2}$. The biasing current $I_Q$ = 1 mA and small-signal differential-mode voltage gain $A_d$ = -250 with $V_{CC}$ = 10 V and $V_{EE}$ = -10 V. Assume that all the transistors are identical and their current gain $\beta$ = 200, $V_{BE(active)}$ = 0.7 V and early voltage $V_A$ = $\infty$. Use voltage equivalence of temperature $V_T$ = 26 mV. [13 marks]

(b) Draw the AC equivalent circuit for the differential amplifier ONLY. Then, draw the differential-mode half circuit and its corresponding small signal equivalent circuit. Finally, prove that the small-signal differential-mode voltage gain of the differential amplifier shown in Figure Q3 is as follows;

$$A_d = \frac{v_{od}}{v_{id}} = -g_m\left(R_C \| r_o\right).$$

[12 marks]

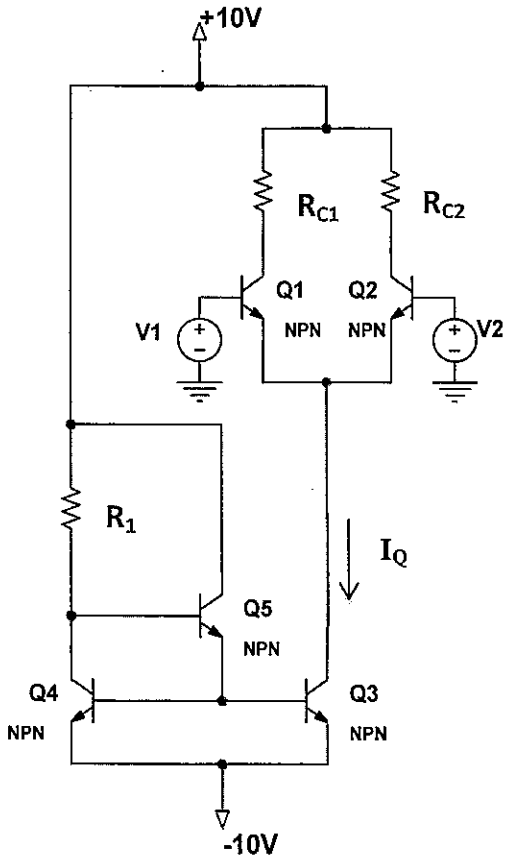


**Figure Q3**

**Continued...**

## Question 4

(a) Draw a high frequency small signal equivalent circuit of the common emitter circuit shown in Figure Q4 (a) using hybrid-$\pi$ model. Ignore the effect of the transistor output resistance, $r_o$. Derive the equations for the higher cutoff frequencies $f_H$. Use the necessary equivalent circuits to show in your derivations.

[11 marks]

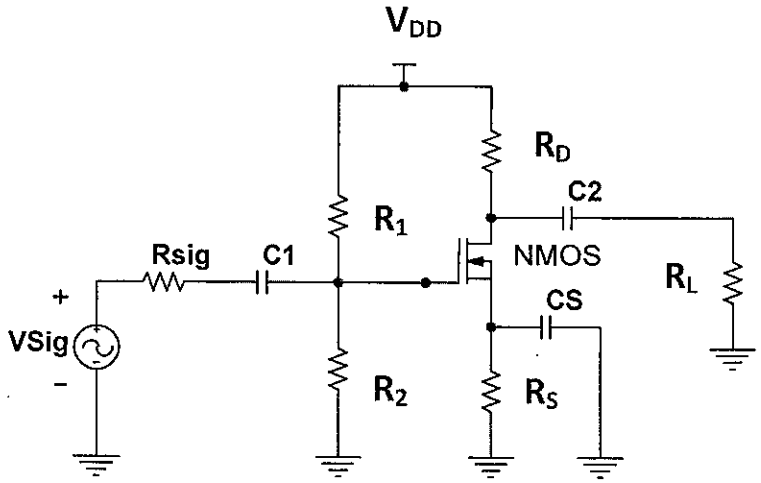


**Figure Q4(a)**

(b) The non-inverting amplifier shown in Figure Q4 (b) is a series-shunt feedback voltage amplifier. Derive the equations for gain $A_f$, output resistance $R_{of}$ and input resistance $R_{if}$. Draw the amplifier equivalent circuit to assist the derivations.

[14 marks]

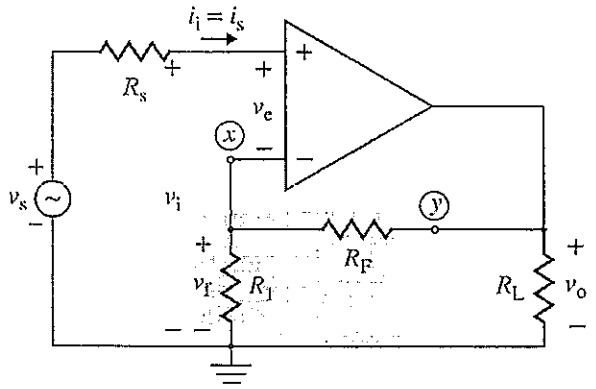


**Figure Q4(b)**

**Continued...**

## Appendix: Useful formula

$$\beta = \frac{I_C}{I_B}$$

$$\alpha = \frac{I_c}{I_E}$$

$$\alpha = \frac{\beta}{\beta+1}$$

$$r_e = \frac{V_T}{I_E}$$

$$r_\pi = (\beta + 1)r_e$$

$$V_T = \frac{kT}{q} \approx 26mV$$

$$I_C = I_S\left(\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right)\left(1 + \frac{V_{CE}}{V_A}\right)$$

$$g_m = \frac{\partial I_C}{\partial V_{BE}} = \frac{I_C}{V_T}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{\beta V_T}{I_C} = \frac{V_T}{I_B}$$

$$r_o = \frac{1}{\partial I_C / \partial V_{CE}} = \frac{V_A}{I_C}$$

$$g_m v_\pi = \beta i_b$$

$$V_{DS} < V_{GS} - V_t;$$

$$I_D = k'\left(\frac{W}{L}\right)\left[(V_{GS} - V_t)V_{DS} - \frac{1}{2}V_{DS}^2\right]$$

$$r_{ds} = \frac{V_{DS}}{i_D}$$

$$V_{DS} > V_{GS} - V_t;$$

$$I_D = \frac{k'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_t)^2$$

$$V_{DS} > V_{DS(SAT)};$$

$$I_D = \frac{k'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_t)^2(1 + \lambda V_{DS})$$

$$V_A = V_M = L_{eff}\left(\frac{dX_d}{dV_{DS}}\right)^{-1} = \frac{1}{\lambda}$$

$$r_o = \frac{V_A}{I_D}$$

$$\phi_f = \frac{kT}{q}\ln\left(\frac{N_A}{n_i}\right)$$

$$\gamma = \frac{\sqrt{2q\varepsilon N_A}}{C_{ox}}$$

$$V_t = V_{to} + \gamma\left(\sqrt{2\phi_f + V_{SB}} - \sqrt{2\phi_f}\right)$$

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$$

$$k' = \mu_n C_{ox}$$

$$V_{OV} = V_{GS} - V_t$$

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = k'\frac{W}{L}V_{OV} = \frac{2I_D}{V_{OV}}$$

$$C_{gs} = C_{gd} = \frac{C_{ox}WL}{2}$$

$$I_D = I_t\frac{W}{L}\exp\left(\frac{V_{OV}}{nV_T}\right)\left[1 - \exp\left(\frac{-V_{DS}}{V_T}\right)\right]$$

**End of Paper**